DESCRIPTION AND USE OF THE double Horizontall Dyall:

WHEREBY NOT ONELY
The hower of the day is ſhewne; but
alſo the Meridian Line is found:

And moſt ASTRONOMICAL Queſtions;
which may be done by the GLOBE,
are reſolved.

~~533. c. 13~~
~~a~~

INVENTED
AND
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K.O.14

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The deſcription, and uſe of the double *HoriZontall diall.*

THere are upon the Plate two ſeverall Dyals. That which is outermoſt, is an ordinary dyal, divided into howers & quarters, and every quarter into three parts which are five minutes apeece: ſo that the whole hower is underſtood to containe 60. minutes. And for this dyall the ſhadow of the upper oblique, or ſlanting edge of the ſtile, or cock, doth ſerve.

The other dyal, which is within, is the *projection of the upper-Hemiſphære, upon the plain of the Horizon:* the *Horizon* it ſelfe is underſtood to be the innermoſt circle of the limbe: and is divided on both ſides from the points of *Eaſt* & *Weſt* into degrees, noted with 10. 20. 30. &c. as far as need requireth: And the center of the Inſtrument is the *Zenith*, or *Verticall point*.

Within the *Horizon* the middle ſtraight line pointing *North* and *South*, upon which the ſtile ſtandeth, is the *Meridian* or twelve a clock line: and the other ſhort arching lines on both ſides of it, are the *hower lines*, diſtinguiſhed accordingly by their figures: and are divided into quarters by the ſmaller lines drawn betweene them: every quarter containing 15. minutes.

The two arches which croſſe the hower lines, meeting on both ſides in the points of interſection of the ſixe a clocke lines with the horizon, are the two ſemicircles of the *Ecliptick* or annuall circle of the ſunne: the upper of which arches ſerveth for the *Summer* halfe yeare; and the lower for the *Winter* halfe yeare: and are therefore divided into 365. daies: which are alſo diſtinguiſhed into twelve moneths with longer lines, having their names ſet downe;and into tenths and fifts with ſhorter lines:and the reſt of the daies with pricks as may plainly be ſeene in the diall.

And this is for thẽ ready finding out of the *place of the Sunne every day*: and alſo for the ſhewing of the *Sunnes yearely motion*, becauſe by this motion the ſunne goeth round about the heavens in the cõpaſſe of a year, making the foure parts, or ſeaſons thereof, namely the *Spring* in that quarter of the *Ecliptick* which begins at the *interſection on the Eaſt* ſide of the dial,& is therefore called the *Vernall interſection*. Then the *Summer* in that quarter of the *Ecliptick* which begins at the *interſection with the Meridian* in the higheſt point next the *Zenith*. After that, *Autumne* in that quarter of the *Ecliptick* which beginneth at the *interſection* on *the Weſt* ſide of the diall,and is therfore called the *Autumnall interſection* and laſtly the *Winter* in that quarter of the *Ecliptick*, which beginneth at the *interſection with the Meridian* in the loweſt point next the *Horizon*.

But beſides this *yearely motion, the Sunne* hath a *diurnall*, or *dayly motion*, whereby it maketh day and night, with all the diverſities and inæqualities thereof: which is expreſſed by thoſe other *circles drawn croſſe the houre lines*;the midlemoſt wherof,being groſſer then the reſt meeting with the *Ecliptick* in the points of thẽ *Vernall*, and *Autumnall interſections*, is the *Equinoctiall*: and the reſt on both ſides of it are called the parallels, *or diurnall arches of the ſunne*, the two outermoſt wherof are the *Tropicks*, becauſe in thẽ the ſun hath his furtheſt *digreſſion* or *Declination* from the *Æquinoctiall*, which is degrees 23 $\frac{1}{2}$: and thence beginneth againe to returne towards the *Equinoctiall*. The upper of the two *Tropicks* in this our Northern *hemiſphere* is *the Tropick of Cancer*, and the ſunne being in it, is higheſt into the North, making the longeſt day of Summer : And the lower next the *horizon* is the *Tropick of Capricorne*; and the ſun being in it, is loweſt into the *South*, making the ſhorteſt day of winter.

Betweene the two *Tropicks* and the *Equinoctiall*, infinite ſuch *parallel circles* are underſtood to be contained: for the Sunne, in what point ſoever of the *Eclipticke* it is carried, deſcribeth by his *lation* a circle parallel to the *Equinoctiall*: yet thoſe *parallels* which are in the inſtrument, though drawne but to every ſecond degree of *declination*, may be ſufficient to direct the eye in imagining and tracing out through every day of the whole yeare in the *Eclipticke*, a proper circle which may be the diurnall *arch of the ſunne* for that day. For upon the right eſtimation of that imaginary parallel doth the manifold uſe of this inſtrument eſpecially rely: becauſe the true place of the Sunne all that day is in ſome part or point of that circle. Wherefore for the better conceiving and bearing in minde thereof, every fift *parallel* is herein made a little groſſer then the reſt.

For this inner dyall ſerveth the ſhadow of the upright edge of the ſtile; which I therefore call the *upright ſhadow*.

And thus by *the eye and view only to behold and comprehend the courſe of the ſunne, throughout the whole yeare both for his annuall and diurnall motion*, may be the firſt uſe of this inſtrument.

II. Vſe. To find the *declination of the Sunne* every day.

Looke the day of the moneth propoſed in the *Ecliptick*, and mark how many degrees the prick ſhewing that day, is diſtant from the *Æquinoctiall*, either on the Summer or winter ſide *viz.* North or South.

Example 1. What will the *declination* of the ſunne bee upon the eleventh day of *Auguſt?* looke the eleventh day of *Auguſt*, & you ſhall find it in the ſixt circle above the *Æquinoctiall*: Now becauſe each parallel ſtandeth (as hath bin ſaid before) for two degrees, the ſunne ſhall that day decline Northwards 12. degrees.

Example 2. What declination hath the Sunne upon the 24. day of *March?* looke the 24. day of *March*, and you ſhall find it betweene the ſecond & third northerne parallels, as it were an halfe and one fift part of that diſtance from the ſecond: Reckon therefore foure degrees for the two circles, and one degree for the halfe ſpace: So ſhall the Sunnes declination be five degrees, and about one fift part of a degree northward that ſame day.

Example 3. What declination hath the Sunne upon the 13. day of *November?* look the 13. day of *Novemb.* and you ſhall finde it below the *Equinoctiall* ten parallels, and about one quarter which is 20. degrees and an halfe ſouthward. So much is the declination. And according to theſe examples judge of all the reſt.

III. Vſe. *To find the diurnall arch, or circle of the ſunnes courſe every day.*

The ſunne every day by his motion (as hath bin ſaid) deſcribeth a circle parallel to the *Equinoctiall*, which is either one of the circles in the diall, or ſome-where betweene two of them. Firſt therefore ſeek the day of the moneth; and if it fall upon one of thoſe parallels; that is the circle of the Sunnes courſe that ſame day: But if it fall betweene any two of the parallels, imagine in your minde, and eſtimate with your eye, another parallel through that point betweene thoſe two parallels keeping ſtill the ſame diſtance from each of them.

As in the firſt of the three former examples, The circle of the Sunnes courſe upon the 11. of Auguſt, ſhall be the very ſixt circle above the *Equinoctial* toward the center.

In example 2. The circle of the *ſunnes courſe* upon the 24. of March ſhall be an imaginary circle between the ſecond and third parallels, ſtill keeping an halfe of that ſpace, and one fift part more of the reſt, from the ſecond.

In example 3. The *circle of the ſunnes courſe* upon the 13. of Novemb: ſhall bee an imaginary circle betweene the tenth and eleventh parallels below the *Equinoctiall*, ſtill keeping one quarter of that ſpace from the tenth.

IIII. Vſe: *To find the riſing and ſetting of the ſunne every day.*

Seeke out (as was laſt ſhewed) the imaginary circle or parallel of the ſunnes courſe for that day, and marke the point where it meeteth with the horizon, both on the *Eaſt* and *Weſt* ſides, for that is the very point of the Sunnes riſing, and ſetting that ſame day, and the hower lines which are on both ſides of it, by proportioning the diſtance reaſonably, according to 15. minuts for the quarter of the hower, wil ſhew the hower of the Sunnes riſing on the *Eaſt* ſide, & the Sunnes ſetting on the *Weſt* ſide.

V. Vſe. To know the reaſon and manner of the *Increaſing & decreaſing* of the *daies & nights* throughout the whole yeare.

When the Sunne is in the *Equinoctiall*, it riſeth and ſetteth at 6. a clock, for in the inſtrument the interſection of the *Equinoctiall*, and the *Ecliptick* with the *Horizon* is in the ſixe a clocke circle on both ſides. But if the ſunne be out of the *Equinoctiall*, declining toward the *North*, the interſections of the parallel of the ſunne with the *horizon* is before ſix in the morning, and after 6. in the evening: and the *diurnall arch* greater then 12. howers; and ſo much more great, the greater the northerne declination is. Againe, if the ſunne be declining toward the South, the interſections of the parallel of the Sunne, with the *horizon* is after ſixe in the morning and before ſixe in the evening: and the *diurnall arch* leſſer then 12. howers; and by ſo much leſſer, the greater the ſoutherne declination is.

And in thoſe places of the *Ecliptick* in which the ſun moſt ſpeedily changeth his declination, the length alſo of the day is moſt altered: & where the *Ecliptick* goeth moſt parallel to the *Equinoctiall* changing the declination, but little altered. As for example, when the ſunne is neere unto the *Equinoctiall* on both ſides, the dayes increaſe and alſo decreaſe ſuddenly and apace; becauſe in thoſe places the *Ecliptick* inclineth to the *Equinoctiall* in a manner like a ſtraight line, making ſenſible declination. Againe when the ſunne is neare his greateſt declination, as in the height of Summer, and the depth of winter, the dayes keepe for a good time, as it were, at one ſtay, becauſe in theſe places the *Ecliptick* is in a manner parallel to the *Equinoctiall*, the length of the day alſo is but little, ſcarce altering the declination: And becauſe in thoſe two times of the yeare, the ſunne ſtandeth as it were ſtill at one declination, they are called the *Summer ſolſtice*, and *Winter ſolſtice*. And in the meane ſpace the nearer every place is to the *Equinoctiall*, the greater is the diverſity of dayes.

Wherefore we may hereby plainly ſee that the common received opinion, that in every moneth the dayes doe æqually increaſe, is erroneous.

Alſo we may ſee that in parallels æqually diſtant frō the *Equinoctiall*, the day on the one ſide is æquall to the night on the other ſide.

VI. Vſe. *To find how farre the Sunne riſeth, and ſetteth from the true East and weſt points, which is called the ſuns Amplitude ortive, and occaſive.*

Seeke out (as was ſhewed in *III. Vſe*) the imaginary circle, or parallel of the ſunnes courſe, and the points of that circle in the *horizon*, on the East and Weſt ſides cutteth the degree of the *Amplitude* ortive, and occaſive.

VII. Vſe. *To finde the length of every day and night.*

Double the hower of the ſunnes ſetting, and you ſhall have the length of the day; and double the hower of the ſunnes riſing, and you ſhall have the length of the night.

VIII. Vſe. *To finde the true place of the ſun upon the dyall, that is, the point of the inſtrument which anſwereth to the place of the ſun in the heavens at any time, which is the very ground of all the queſtions following.*

If the dyall bee fixed upon a poſt: Looke what a clocke it is by the outward dyall, that is, looke what

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If the dyall bee fixed upon a poſt: Looke what a clocke it is by the outward dyall, that is, looke what hower and part of hower the ſhadow of the ſlanting edge of the ſtile ſheweth in the outward limbe. Then behold the ſhadow of the upright edge, and marke what point thereof is upon that very hower, and part in the inner dyall among the parallels, that point is the true place of the Sun at the ſame inſtant.

If the dyall bee not fixed, and you have a *Meridian line* noted in any window where the Sun ſhineth: place the *Meridian* of your dyall upon the *Meridian* line given, ſo that the top of the ſtile may point into the North: and ſo the dial is as it were fixed, wherefore by the former rule you may finde the place of the Sunne upon it.

If the dyall be not fixed, neither you have a *Meridian line*, but you know the true hower of the day exactly: hold the diall even and parallel to the *horizon*, moving it till the ſlanting edge of the ſtile caſt his ſhadow juſtly upon the time or hower given: for then the diall is truly placed, as upon a poſt. Seek therfore what point of the upright ſhadow falleth upon that very hower, and there is the place of the Sunne.

But if your diall be looſe, and you know neither the Meridian nor the time of the day. Firſt, by the day of the month in the Ecliptick, find the ſunnes parallel, or diurnall arch for that day, then holding the diall levell to the horizon, move it every way untill the ſlanting ſhadow of the ſtile in the outward limbe, and the upright ſhadow in the ſunnes diurnal arch, both ſhew the very ſame hower and minute, for that very point of the ſunnes parallel, which the upright ſhadow cutteth, is the true place of the Sun on the diall at that preſent.

But note that by reaſon of the thicknes of the ſtile, and the bluntneſſe of the angle of the upright edge, the Sunne cannot come unto that edge for ſome ſpace before and after noone. And ſo during the time that the Sunne ſhineth not on that upright edge, the place of the Sunne in the diall cannot bee found. Wherefore they that make this kind of double diall, are to be carefull to file the upright edge of the ſtile as thinne and ſharpe as poſſible may be.

That which hath here bin taught concerning the finding out the Sunnes true place in the dyal, ought perfectly to be underſtood, that it may be readily, and dexterouſly practiſed, for upon the true performance thereof dependeth all that followeth.

IX. Vſe. *To find the howre of the day.*

If the diall be faſtned upon a poſt: the hower by the outward diall, or limbe, is knowne of every one: & the upright ſhadow in the ſuns parallel, or diurnal arch will alſo ſhew the very ſame hower.

But if the dyall be looſe, either hold it or ſet it parallel to the horizō, with the ſtile pointing into the North and move it gently every way untill the hower ſhewed in both dials exactly agreeth, or which is all one, find out the true place of the Sunne upon the dyall, as was taught in the forme queſtion, for that point among the hower lines ſheweth the hower of the day.

X. Vſe. *To find out the Meridian, and other points of the Compaſſe.*

Firſt you muſt ſeeke the true hower of the day (by the laſt queſtion) for in that ſituation the Meridian of the dyall ſtandeth directly North and South: and the Eaſt pointeth into the Eaſt, and the Weſt into the weſt, and the reſt of the points may bee given by allowing degr: 11. $\frac{1}{4}$ unto every point of the compaſſe.

XI Vſe. *To find out the Azumith of the ſun, that is, the diſtance of the Verticall circle, in which the ſun is at that preſent, from the Meridian.*

Set your dyal upon any plain or flat which is parallel to the horizon, with the Meridian pointing directly North and South, as was laſt ſhewed: then follow with your eye the upright ſhadow in a ſtreight line, till it cutteth the *horizon*: for the degree in which the point of interſection is, ſhall ſhew how farre the ſuns *Azumith* is diſtant from the Eaſt and weſt points, and the complement thereof unto 90. ſhall give the diſtance thereof from the Meridian.

XII. Vſe. *To find out the Declination of any Wall upon which the ſun ſhineth, that is, how farre that wall ſwerveth from the North or South, either Eaſtward or Weſtward.*

Take a board having one ſtreight edg, & a line ſtrickē perpēdicular upō it; apply the ſtreight edg unto the wal at what time the ſun ſhineth upon it, holding the board parallel to the horizon: Set the dyal thereon, & move it gently every way, untill the ſame hower and minute be ſhewed in both dyals: and ſo let it ſtand: then if the dyall have one of the ſides parallel to the Meridian, ſtrike a line along that ſide upon the board, croſſing the perpendicular, or elſe with a bodkin make a point upon the board, at each end of the Meridian, and taking away the inſtrument from the board, and the board from the wall, lay a ruler to thoſe two points, & draw a line croſſing the perpendicular: for the angle which that line maketh with the perpendicular, is the angle of the declination of the wall. And if it bee a right angle, the wall is exactly Eaſt or weſt: but if that line bee parallel to the perpendicular, the wall is direct North or South without any declination at all.

You may alſo finde out the declination of a wall, if the dyall be fixed on a poſt not very far from that wall, in this maner. Your board being applyed to the wal, as was ſhewed, hang up a thred with a plummet, ſo that the ſhadow of the thred may upon the board croſſe the perpendicular line: make two pricks in the ſhadow and run inſtantly to the dyall and looke the horizontall diſtance of the ſunnes Azumith, or upright ſhadow from the Meridian. Then through the two pricks draw a line croſſing the perpendicular; and upon the point of the interſection, make a circle æquall to the horizon of your inſtrument, in which circle you ſhall from the line through the two pricks meaſure the horizontall diſtance of the upright ſhadow, or Azumith from the Meridian, that way toward which the Meridian is: draw a line out of the center, to the end of that arch meaſured: and the angle which this laſt line maketh with the perpendicular, ſhall be æquall to the declination of the wall.

XIII. Vſe. *How to place the dyall upon a poſt without any other direction but it ſelfe.*

Set the dyall upon the poſt, with the ſtile into the North, as neare as you can gueſſe: then move it this way and that way, till the ſame hower and minute be ſhewed, both in the outward and inward dyals by the ſeverall ſhadowes, as hath bin already taught, for then the dyal ſtandeth in its trueſt ſituation; wherefore let it be nailed downe in that very place.

XIIII. Uſe. *To find the height of the ſun at high noone euery day.*

Seeke out the diurnall Arch or Parallel of the Sunnes courſe for that day, (by *Vſe III.*) and with a paire of Compaſſes, ſetting one foot in the center, and the other in the point of interſection of that parallel with the Meridian, apply that ſame diſtance unto the Semidiameter divided: for that meaſure ſhall therein ſhew the degree of the Sunnes altitude above the horizon that day at high noone.

XV. *Vſe. To finde the height of the Sunne at any houre or time of the day.*

Seeke out the diurnall Arch, or parallel of the Sunnes courſe for that day: and marke what point of it is in the very houre and minute propoſed. And with a paire of Compaſſes, ſetting one foot in the center, and the other in that point of the parallel, apply the ſame diſtance upon the Semidiameter divided: for that meaſure ſhall ſhew the degree of the ſunnes altitude above the horizon at that time.

And by this meanes you may finde the height of the Sun above the horizon at every hower throughout the whole yeare, for the making of rings and cylinders and other inſtruments which are uſed to ſhew the hower of the day.

XVI. Vſe. *The height of the Sunne being given, to find out the hower, or what it is a clocke.*

This is the converſe of the former: Seeke therefore in the Semidiameter divided, the height of the Sunne given. And with a paire of Compaſſes, ſetting one foot in the center, & the other at that height, apply the ſame diſtance unto the diurnall arch, or parallel of the Sunne for that day: for that point of the diurnall arch, upon which that ſame diſtance ſhall light, is the true place of the ſunne upon the diall; and ſheweth among the hower lines, the true time of the day.

XVII Vſe. *Conſiderations for the uſe of the inſtrument in the night.*

In ſuch queſtions as concerne the night, or the time before ſunne riſing, and after ſunne ſetting, the inſtrument repreſenteth the lower hemiſphære, wherein the ſoutherne pole is elevated. And therefore the parallels which are above the Æquinoctiall toward the center, ſhal be for the ſoutherne, or winter parallels: and thoſe beneath the Æquinoctiall, for the Northerne or Summer parallels; and the Eaſt ſhall be accounted for Weſt, and the weſt for Eaſt, altogether contrary to that which was before, when the inſtrument repreſented the upper hemiſphære.

XVIII. Vſe. *To find how many degrees the ſunne is under the horizon at any time of the night.*

Seeke the declination of the ſunne for the day propoſed (by *Vſe* II.) And at the ſame declination on the contrary ſide imagine a parallel for the ſun that night: and marke what point of it is in the very hower and minute propoſed: And with a paire of compaſſes, ſetting one foot in the center, and the other in that point of the parallel, apply that ſame diſtance unto the ſemidiameter divided: for that meaſure ſhall ſhew the degree of the ſunnes depreſſion below the horizon at that time.

XIX. Vſe. *To find out the length of the Crepuſculum, or twylight, every day.*

Seeke the declination of the ſunne for the day propoſed (by *Vſe* II.) And at the ſame declination on the contrery ſide imagine a parallel for the ſun that night. And with a paire of compaſſes ſetting one foote in the center

ter, and the other at 72. degrees upon the ſemidiameter divided, apply that ſame diſtance, unto the ſunnes nocturnall parallel: for that point of the parallel, upon which that ſame diſtance ſhal light, ſheweth among the hower lines, the beginning of the twilight in the morning, or the end of the twilight in the evening.

XX. Uſe. *If the day of the month be not knowne, to find it out by the dyall.*

For the working of this queſtion, eyther the dyall muſt be fixed rightly on a poſt, or elſe you muſt have a true Meridian line drawne in ſome window where the ſun ſhineth, wherefore ſuppoſing the dyall to bee juſtly ſet eyther upon the poſt, or upon the Meridian, Looke what a clock it is by the outward dyall, and obſerve what point of the upright ſhadow falleth upon the very ſame minute in the inner dyall, and through that ſame point imagine a parallel circle for the ſunnes courſe; that imaginary circle in the Ecliptick ſhall cut the day of the month.

These Inſtrumentall dyalls are made in braſſe by Elias Allen *dwelling over againſt* S^{t}. Clements *Church without Temple barre.*

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